Modelling Complex Resource Requirements in Business Process Management Systems

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Abstract

Real-world business processes are resource-intensive. In work environments human resources usually multitask, both human and non-human resources are typically shared between tasks, and multiple resources are sometimes necessary to undertake a single task. However, current Business Process Management Systems focus on task-resource allocation in terms of individual human resources only and lack support for a full spectrum of resource classes (e.g., human or non-human, application or non-application, individual or teamwork, schedulable or unschedulable) that could contribute to tasks within a business process. In this paper we develop a conceptual data model of resources that takes into account the various resource classes and their interactions. The resulting conceptual resource model is validated using a real-life healthcare scenario.

Keywords

Resource modelling, business process management, process automation, conceptual data modelling.

INTRODUCTION

Surveys over the past five years have shown business process management to be the number one concern of senior executives (Gartner 2010). There have also been many initiatives over the past few years in both academia and in industry to capture the core operations of businesses as business process models and use them as a basis for process improvement and for automation purposes. This has resulted in a well-defined business process life cycle, the emergence of process-aware information systems (Dumas 2005), and well-accepted process modelling languages such as the Business Process Modelling Notation (BPMN) (OMG 2009) and Event-driven Process Chains (EPCs) (Keller et al. 1992).

Business models are now becoming prevalent in many organisations and Business Process Management Systems (BPMSs) are increasingly being used for effective and efficient business operations. A BPMS offers a holistic approach to process management and provides a number of analysis and simulation tools for process redesign and improvement. To provide end-to-end support, many business operations now need careful integration of automated activities, carried out by software systems, with human-driven activities, that require human judgement. Executable processes are also being used in business process automation engines such as YAWL (ter Hofstede et al. 2010) and the Oracle BPEL Process Manager (Oracle 2009).

However, most practical and academic work to date has been dedicated to modelling control flow dependencies between activities. Business process models typically abstract away from the resource perspective (i.e., who is to carry out the activities) or provide a simplistic view of resource participating in business operations (e.g., only one resource works on one activity at a time). Even in widely-used process modelling languages such as BPMN and EPC, complex resource interactions between activities and resources are ignored. For instance, BPMN models only allow for modelling pools and lanes to define the roles of the resources that may carry out an activity. EPCs also focus on the control flow perspective only. As a result, many Business Process Management Systems only cater for simple one-to-one resource allocation strategies (e.g., role-based or direct-allocation).

In practice, though, people often work in teams to accomplish an activity. Some team structures are simple and follow the company's organisational hierarchy. For instance, a leave application form submitted by an employee is first approved by their immediate supervisor and is then signed off by the head of the department, before being sent to the human resources department. We can model this process easily by splitting it into two sequential activities, supervisor's approval and manager's approval, to ensure that only one resource is responsible for one activity at a time. But for more complex team structures, it may be awkward or even impossible to ignore the cooperating resource requirements needed for an activity. For instance, a surgical operation requires a large team of skilled people who play different roles (surgeons, anaesthesiologists, nurses, etc) and needs the presence of specialised equipment and infrastructure (an operating theatre, surgical instruments, cardiac monitors, etc). Often more than one resource is required for a particular role. For instance, in a car manufacturing plant, the role of 'welder' requires not only the human worker, but also non-human resources such as welding torches, safety goggles, and perhaps even robotic assistants. As business process automation systems mature, richer support for modelling and allocating resources is clearly necessary.

In this paper we define the complex relationships between multiple resources working together on an activity, the issues that can arise from the interactions between these resources and processes, and the resulting implications for business process automation systems that must support this complex resource structure. Based on our experiences with the actual resourcing requirements of real-world business operations – in the domains of manufacturing, asset management, film production and healthcare – we provide a conceptual data model of resources that captures resource classification, resource availability, resource calendars, resource assignments, and resource logging requirements.

RELATED WORK

There has been relatively limited research into resource modelling in the context of Business Process Management Systems (van der Aalst et al. 2003). Bussler and Jablonski (1996) presented one of the first broad attempts to model various perspectives of workflow systems in an integrated manner, including detailed consideration of the organisational view. Several subsequent researchers (zur Muehlen 2004; van der Aalst and Kumar 2001) have developed meta-models, i.e., object models describing the relation between workflow concepts. However, zur Muehlen (2004) considered only human resources, and van der Aalst and Kumar (2001) concentrated on the concept of modelling a team. Lerner et al. (2000) presented an abstract resource model with a focus on the efficient management of resources rather than the richer specification of resource requirements in a workflow context.

Russell *et al.* (2005) discovered that issues associated with the resource perspective of workflows have been largely neglected. To fill this vacuum, they identified a comprehensive list of 43 resource patterns that capture the various ways in which resources interact with workflows. Again, however, most of these patterns focus on individual human resources interacting with a task, with only two exceptions. Their *Additional Resources* pattern captures the situation where a given resource requests additional resources to assist in the execution of a work item, and their *Simultaneous Execution* pattern models the ability of a resource to execute more than one work item simultaneously (i.e., to multi-task). Our research thus complements the previous work, by defining a data model suitable for arbitrarily complex resource requirements, including resources that contribute to multiple tasks and tasks that require multiple resources, resource allocation taking into account resource availability, and real-time resource utilisation logging.

A number of business process and enterprise modelling approaches provide graphical notations for specifying resources associated with a business process. As mentioned before, BPMN (OMG 2009) defines modelling pools and lanes to capture the roles of human resources that may carry out an activity. IDEF0 (ICAM 1981) offers a functional language for modelling of business processes and defines a so-called mechanism to record the resources used to complete each task in a process. ARIS (Scheer and Nüttgens 2000), a well-known approach to enterprise modelling, proposes a view model that involves a control view for capturing the control flow of business processes (using EPC) and an organisational view for specifying the human resources associated with the process. EEML (Krogstie 2008) is another approach for enterprise modelling which combines structural modelling, business process modelling, goal modelling, and resource modelling. It specifies a group of icons which represent various resources required and defines different types of relations between human resources in an organisational setting. Our research is however different from these approaches as we focus on developing a resource conceptual model that will not only be used for the purposes of documentation and communicating with stakeholders, but also as a basis for automation and analysis in BPMS tools.

RESEARCH METHODOLOGY

This is a qualitative research study which in principle conforms to the Design Science methodology used in information systems research (Hevner et al. 2004). Also, it is similar in nature to previous research that we conducted which involved collecting and analysing process requirements of film productions (Ouyang et al. 2008). A successful adoption of the Design Science methodology in the previous research has further assured us to apply the same methodology in this study.

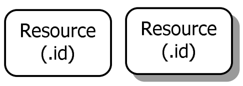
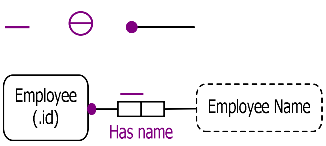
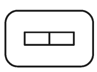
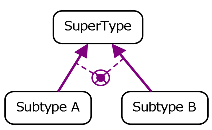
Hence, we follow the seven guidelines of the methodology as reported by Hevner et al (2004). The design of a purposeful IT artefact (Guideline 1 – *Design as an Artefact*), i.e. a conceptual data model which captures comprehensive resource requirements, follows the observation in several application domains (manufacturing, asset management, film production, and healthcare) that properly capturing resource requirements and resource interactions within a business process is widely regarded as important but not sufficiently addressed in existing BPMSs (Guideline 2 – *Problem Relevance*). Through interviews with stakeholders, on-site observations, and literature review, sufficient access to domain expertise was available for the design and development of our artefact as well as validation of the design to a certain extent. The artefact was evaluated through a case study in a given application domain (Guideline 3 – *Design Evaluation*). Our research aims to contribute to the field of BPM (Guideline 4 – *Design Contributions*) and due to the adoption of a formal conceptual modelling technique in the design of the artefact we regard the result as rigorous (Guideline 5 – *Design Rigor*). The research process though is not finished and the resulting artefact requires continuous questioning, revision, extension, and evaluation (Guideline 6 – *Search Process*). This process is guided by exposing the research to both the IT community, among others through publications, and application domains such as healthcare, film production, and manufacturing (Guideline 7 – *Communication of Research*).

This paper reports on the results from an initial phase with the emphasis on the use of conceptual modelling techniques to carry out the requirements analysis for complex resource interactions within a BPMS. Conceptual models are used "to represent both static phenomena (e.g., things and their properties) and dynamic phenomena (e.g., events and processes) in some domain" (Wand and Weber 2002). We employed the case study research methodology (Yin 2009) for evaluation purposes in this paper. In line with the principles governing Design Science research, we produced a viable IT design artefact in the form of a conceptual data model, which can later serve as a reference for instantiation within any BPMS. The resulting conceptual data model for resource interactions was evaluated using a real-life case study from the healthcare domain.

Conceptual Data Modelling

There are a number of well-known conceptual data modelling techniques, namely Entity-Relationship Modelling (ER) (Chen 1976), the Unified-Modelling Language (UML) (OMG Group 2010) and Object Role Modelling (ORM) (Halpin 2008). All provide notations and techniques for designing conceptual data models and each has its own advantages and disadvantages. ER modelling is popular for deriving database designs, but has difficulty capturing complex constraints. UML class diagrams are ideally suited to object-oriented computer software modelling as they include software concepts such as classes and attributes and the relationships between classes, as basic features. However, they are less well-suited to developing and validating conceptual data models with domain experts (Halpin 1998). ORM is "a fact-oriented approach" especially designed for conceptual analysis (Halpin 2008). ORM models depict the objects of interest and the relationships between these objects in a precise manner. In this paper, we use ORM because ORM notation can be easily understood by a non-technical audience, yet the ORM technique is expressive enough to capture the business rules and constraints of interest for resource modelling. Table 1 provides a brief summary of the ORM symbols used in this paper.

Table 1. A selection of Object Role Modelling symbols

Construct name	Symbol/s	Description
Entity type with reference mode		An entity of interest with a way to identify each object of that type. A shadow indicates that there is a duplicate copy of that entity in other parts of the model.
Value type		The label of an entity (e.g., an Employee object has a label 'employee name')
Fact types (unary, binary, ternary)		The relationships between entities and value types. The number of roles is reflected in the kind of fact type.
Constraints		An internal uniqueness constraint is represented by a bar above or below a role in a fact type. An external uniqueness constraint symbol is used between two or more fact types. A mandatory role constraint (a black dot) indicates that each object should be involved in this fact type.
Objectification		A fact type can be objectified as an entity type that can play roles with other fact types.
Subtyping		An entity can be in a subtype relationship with other entities. A circled cross ⊗ with a dot • indicates that the subtypes partition the super type (exclusively and exhaustively.)

REQUIREMENTS ANALYSIS

Based on an extensive literature review on resource modelling in process automation and workflow systems, combined with our own experience in developing business process models in different application domains, we identified the need for a richer representation of resources within process modelling languages and subsequently in business process management systems. Below we briefly present three scenarios in different domains to highlight some of the important requirements.

Car Manufacturing Scenario

This scenario is based on the car manufacturing process descriptions we collected from relevant books and websites. The assembly line within a car manufacturing plant is a collaborative process between human workers and the machines that they rely on to get the job done. Tasks such as painting a car body are primarily done by robots, tasks such as quality control checks are done by human workers, whereas other tasks such as bolting wheels to a car body are done by a combination of assembly line workers and machines. To develop a business process model of such a process without considering the involvement of these resources would not give us an accurate picture. For instance, performance analysis of such processes requires us to consider the way different resources work together. Hence, one needs to take into account both *human resources* and *non-human resources* to support collaborative work arrangements involving multiple resources of different types.

Surgery Scheduling Scenario

This scenario is based on information we collected from interviews with clinicians and on-site work shadowing in several German hospitals, and supplemented by a literature review of relevant clinical conferences. It also provides the context for the case study in this paper. A typical surgical procedure involves many human resources (e.g., surgeons, anaesthesiologists, scrub nurses, etc) and non-human resources (e.g., operating theatres, technical equipment, instrument sets, capacity of post-operative intensive care), and requires careful coordination of these resources. In general medical resources are scarce and, hence, are shared among different operations. They thus need to be scheduled in advance to ensure their availability at the right time. A surgical procedure is usually scheduled based on factors such as medical priority, resource availability and expected duration. Sometimes an operation's completion time may be delayed due to unpredictable events, causing other operations that need the same resources to be re-scheduled. In addition, resources may be subject to certain business rules which impose further restrictions on the scheduling of operations. For example, surgical instrument sets need to undergo a time-consuming sterilisation procedure between uses. Hence, to enable both efficient scheduling of surgical procedures and well-managed resource utilization, one must have knowledge of the *availability* of the resources required as well as the related *resource business rules*.

Film Production Scenario

This scenario is based on information collected from a previous project (Ouyang et al. 2008) that we conducted with the Australian Film Television and Radio School. A film production process includes daily production activities that occur over weeks or months and usually engages a team consisting of the cast and crew, specialised film production equipment, and a variety of non-technical resources such as catering. As shooting often occurs on location, it involves coordinating resources in a geographically distributed and mobile work environment, and we thus need to keep track of the *resource locations*. To ensure that production proceeds according to schedule and within budget, the film's progress is measured on a daily basis. This includes logging and monitoring of the related resource utilisation, e.g., individual cast and crew's working time (which is necessary for calculating salaries), and the daily usage of stock footage (which is required to work out how much film the production has left on hand). The quality of the resource utilisation log can make a considerable difference to progress monitoring. Hence, it is important to ensure the accuracy of resource utilisation data, by applying appropriate *resource logging* mechanisms.

RESOURCE CONCEPTUAL MODEL

Based on the above resource requirements analysis, we have defined a conceptual model to capture complex resource requirements in a generic manner. Of course, any conceptual model is an abstraction of reality. To evaluate whether a conceptual model is fit for its purpose, one needs to understand the modelling rationale. Our resource conceptual model will not only be used for the purposes of documentation and for communicating with stakeholders, but also as a basis for automation and analysis in workflow tools. Specifically, the model was developed with the following objectives in mind:

- *Design-time resource specification and analysis*: The model must contain sufficient resource-related information to support design-time specification and analysis. For instance, it must capture all the different types of resources involved and the quantity of each resource required while a task is being carried out.

- *Automated support for resource management*: The model must contain sufficient task-resource information for automation support. Models must capture possible interactions between resources and tasks (e.g., active vs. passive involvement, resource assignment and delegation privileges).
- *Resource scheduling and availability*: To enable intelligent resource allocation and scheduling, the workflow system must be aware of the current state of a resource as well as the availability of resources in the future (e.g., from a resource calendar). The system must also be aware of other existing commitments of resources (e.g., if a resource is already booked at a specific time). Each resource may have an associated *schedule* and *history* and a calendar. A schedule is a list of work items that a resource is committed to undertaking at specified future times whereas a history or work log is a list of work items that a resource has completed (successfully or otherwise) at some time in the past.
- *Resource usage monitoring and post-execution process analysis*: To be able to accurately reflect the current state of a resource, resource usage must be carefully monitored. The conceptual model must capture the execution log data required for monitoring and post-execution analysis purposes (e.g., start and completion times of resource activities, machine downtimes, etc). The Business Process Management System must have access to a resource model that captures all resource-related information needed to support scheduling and planning of resources for tasks, and recording of histories of resource utilisation.

We used the ORM technique to construct our resource conceptual model. For illustrative purpose, we divided the model into four modules: *resource classification*, which defines both human and non-human resources; *multiple resources assignment*, which specifies how multiple resources are involved in carrying out a task in a business process; *resource calendar*, which captures the information about a resource's status (including its availability), resource location, and resource business rules; and *resource utilisation logging*, which logs real-time resource utilisation data and events during process enactment. We describe the four modules in detail.

Resource Classification

Figure 1 specifies a general classification of resources involved in business processes. A *resource* is classified as either *human* or *non-human*. Modelling of the human resources in Figure 1 was based on prior research into resource meta-models (zur Muehlen 2004), organisational modelling (van der Aalst et al. 2003) and modelling of teams (van der Aalst and Kumar 2001) in the context of workflow management. A human resource is typically a member of an organisation and holds a specific *position* within that organisation. He/she may have one or more corresponding *roles* and may possess *capabilities* that further clarify their suitability for various kinds of work. These capabilities may include formal qualifications, learned skills, or previous work experience of which more details are specified by *capability values*. An *organisational group* is a formal grouping of resources that undertake work items relating to a common set of the organisation's business goals. There are different *organisational group types* such as 'centre', 'faculty', 'department', etc. An organisation is structured according to a certain organisational hierarchy, and each position (at a lower organisational level) may be subordinate to another position (at a higher organisational level) and must report to that senior position. *Teams* are formed for a specific purpose, by people who play certain roles, hold certain positions, and/or possess required capabilities. Teams may be part of an organisational group or orthogonal to the organisational structure, e.g., a conference's programme committee is typically formed from individuals from unrelated departments or institutions.

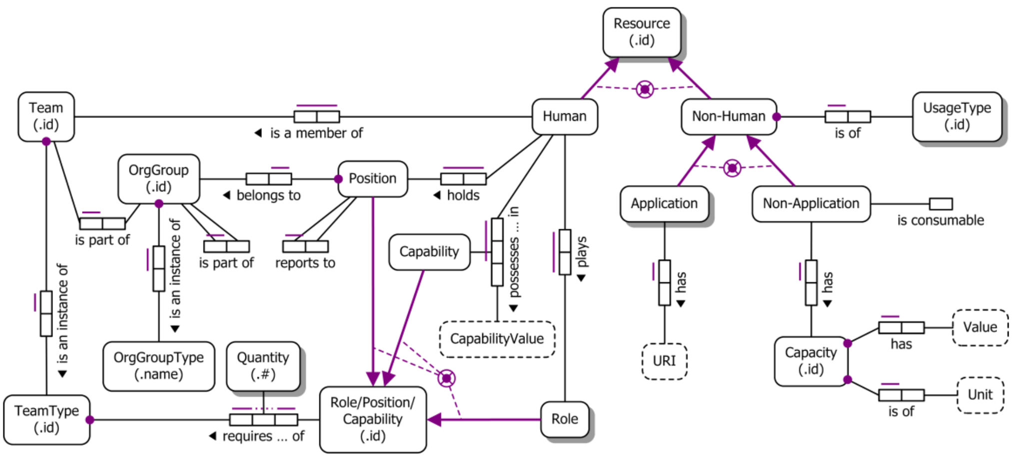


Figure 1: Resource classification Object Role Model

As mentioned previously, in addition to human resources, non-human resources are, in most cases, also required to complete a task in a business process. However, there is so far no existing research into non-human resource modelling in the context of workflow management and no existing Business Process Management System provides support to the specification of non-human resources within process models. Therefore, in addition to modelling of human resources, we defined non-human resources in Figure 1 based on our experience in developing business process models in different domains. In general, each non-human resource is of a certain usage type, e.g., bolting machine, operating room, bandage, camera, etc. We divide non-human resources into *application* and *non-application* resources. An application resource may be a software tool or a web service which is registered with a *URI*. A non-application resource may be *consumable* (e.g., machine oil, sound tape) or *durable* (e.g., surgical instruments, lighting equipment). There is usually a capacity (in terms of size, volume, lifespan, etc) associated with a non-application resource. For example, a hospital may have seven operating rooms, a sound tape may provide up to an hour of recording, and an oil container may hold up to ten litres of engine oil. For consumable resources (e.g. oil, water, paper), their capacity can be used to estimate their remaining useful life, while for durable resources (e.g., a robotic arm, heart-lung machine, transport vehicle), their capacity may indicate the duration of their maintenance cycle.

Multiple Resources Assignment

The resource classification module in Figure 1 enables the specification of all possible resources within process modelling. Based on that, we developed the conceptual module shown in Figure 2, which captures the way multiple resources are assigned when they work on the *same* task. Most existing research into Business Process Management Systems has focused on single resource assignment. In their seminal work, van der Aalst and Kumar (2001) investigated the concept of a team of human resources in the context of workflow management. However, the notion of multiple resources is different from teams as multiple resources involve both human and non-human resources and are not grouped following pre-defined rules. Thus this notion can have a big impact on the enabling rule of a task. For instance, many tasks are enabled if and only if all the resources required are available. In other cases it is possible that some of the resources (e.g., extra personnel) are optional while others (e.g., necessary equipment) are mandatory.

In our current research, we are especially interested in the specification requirements for multiple resources assignment. For this purpose, we introduce the concepts of *primary* resource and *additional* resource. A primary resource is responsible for managing a task and for making sure that all the additional resources are available for carrying out the task. Thus the primary resource will take charge of a corresponding task instance from a workflow engine. Only human resources and application (non-human) resources can be assigned as primary resources. In the case of an application being a primary resource, it works on a *system task* which does not need human interaction (cf. a *user task*). Any resource can be assigned as an additional resource. For example, a surgeon is in charge of a surgical procedure which also requires an anaesthesiologist, one scrub nurse, one nurse anaesthetist, one circulating nurse, an operating room, an endoscopic kit, etc. Resources can be selected in terms of their roles or usage types, as a team, or specifically through unique resource identifiers.

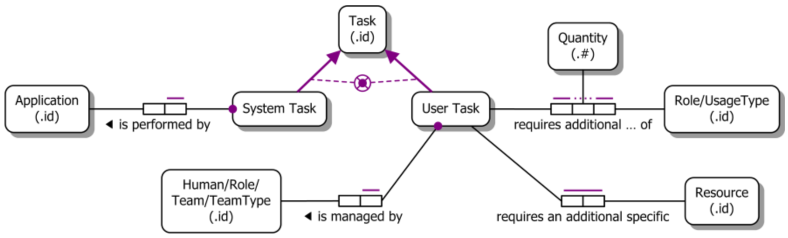


Figure 2: Multiple resources assignment Object Role Model

Resource Calendar

The resource classification and assignment modules above allow us to specify multiple resources requirements for tasks in a business process. When the process is carried out, the execution of tasks is often tied to the availability of resources. Associating a resource calendar with a resource gives us with the ability to specify the availability of resources in a more fine-grained manner. The information stored in the calendar is not only essential for effective task execution but is also very useful for scheduling purposes.

Figure 3 shows our model of a resource calendar module for both human and non-human resources. It specifies resource availability status (on the left of the broken line) as well as resource-related business rules (to the right of the line). The availability status of a resource is given by a set of generic life cycle *states*. Examples of such states are *available*, *unavailable*, *occupied*, *reserved*, *blocked*, etc. We define a notion of *resource status* to capture the fact of a resource being in a certain state. Resource status spans a time *period* as specified using a start time and an end time. A resource can be in a certain state for a particular *reason*. For example, an actor is *unavailable* because he is *on leave*; a surgeon is occupied because s/he is *in an operation*, a bolting machine is *blocked* because it is *under maintenance*, etc. The model also takes into account the notion of locations in which a resource can be situated during a certain time period.

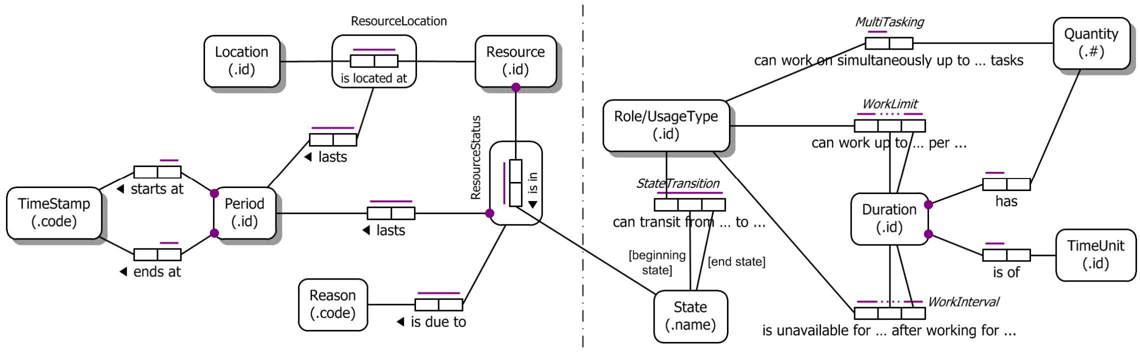


Figure 3: Resource calendar Object Role Model

Next, resources may be subject to business rules that can affect their availability and the scheduling of tasks. These can be specified in terms of *state-transition rules* which impose restrictions on how resources change from a beginning state to an end state. For example, the rule that a medical instrument set in an *occupied* state (in use) can only change to a *blocked* state (for sterilisation) reflects the fact that the instrument set will not be available for reuse immediately after surgery but needs to be sterilised first. In addition, our resource calendar model also captures three other types of policy-based rules. The first two, the *work-interval rule* and the *work-limit rule*, are concerned with safety, health or maintenance policies. For example, during a film shoot, each cast and crew member needs a 45-minute meal break after having worked for four hours, and should not work for more than nine hours a day; an oil pump needs a 3-hour break after running for 200 hours. The last rule is about resource *multi-tasking*. For example, a circulating nurse can work for up to a certain number of operations at the same time; a production coordinator can simultaneously monitor the shooting status of up to three shooting units.

Resource Utilisation Logging

Figure 4 shows a basic module for logging resource utilisation information during process enactment (i.e., at run-time). First we introduce the concept *work item* which is defined as an instance of a task in a given *case*. For example, "conduct diagnostic tests as precondition for a surgical procedure" is a task and "conduct diagnostic tests as precondition for the surgical procedure with case number 12AB78" is a corresponding work item. A task is a design-time modelling concept while a work item is the corresponding run-time concept.

No matter whether a resource is a primary resource or an additional resource assigned to a task, we define a general notion of *resource utilisation* to capture the fact that a resource is used by the corresponding work item. The model records the use's *starting* and *ending times*, the *quantity* of the resource being used, and the *location* where the resource is situated. Such a resource log is very useful for retrospective process analysis with respect to controlling and enterprise reporting. For instance, the log data can be used to calculate the average percentage of resource usage and consumption.

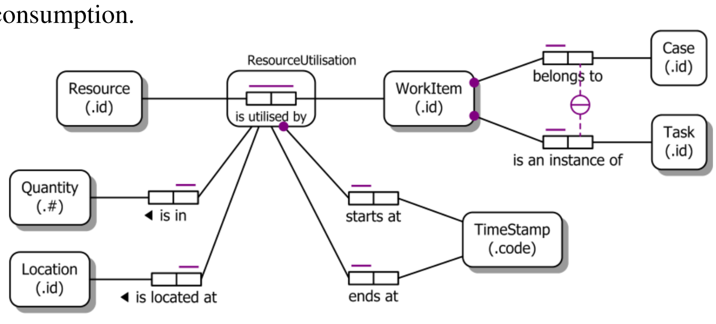


Figure 4: Resource utilisation logging Object Role Model

CASE STUDY: A PERIOPERATIVE CARE PROCESS

We have applied our resource conceptual model in the context of a perioperative care process as part of a collaboration between Queensland University of Technology and GECKO mbH (www.gecko.de), a German software company. As part of an ongoing research & development project of GECKO, the domain of perioperative clinical processes has been intensively investigated since the summer of 2009. The project aims at introducing Business Process Management (BPM) technology into core value-adding clinical processes that are resource-intensive and coordination-centric. The associated requirements analysis was based on on-site work shadowing and conducting interviews with clinicians in several German hospitals, supplemented by a literature review as well as attending relevant clinical conferences. In general, this domain possesses a high potential for innovative BPM solutions that are resource-aware and capable of supporting the scheduling of these resources.

The term *perioperative care* refers to any clinical activity that is related to a patient's surgery and takes place between admission to the hospital and post-operative transfer to a ward. Activities may be primary, i.e., directly applied to the patient, or secondary, i.e., part of supportive process. The typical perioperative environment is a surgical suite that concurrently operates a large number of operating rooms. For any surgical case, many human (e.g., surgeons, anaesthesiologists, scrub nurses) and non-human resources (e.g., technical medical equipment, instrument sets, capacity for post-operative care) are required. In general these resources are limited and shared among concurrent cases of perioperative care. They are usually scheduled in advance for each operation.

Figure 5 depicts a simplified perioperative care process (with selected tasks) and the resource requirements associated with each of the tasks. The process model uses four basic notations from the YAWL workflow language, namely atomic and composite tasks, and input and output conditions (signalling the start and end of a process). Also, we add annotations to each task specifying the task's resource requirements. As per our resource conceptual model, each task has a primary resource (specified under [primary]) and may require additional resources (specified under [additional, quantity]).

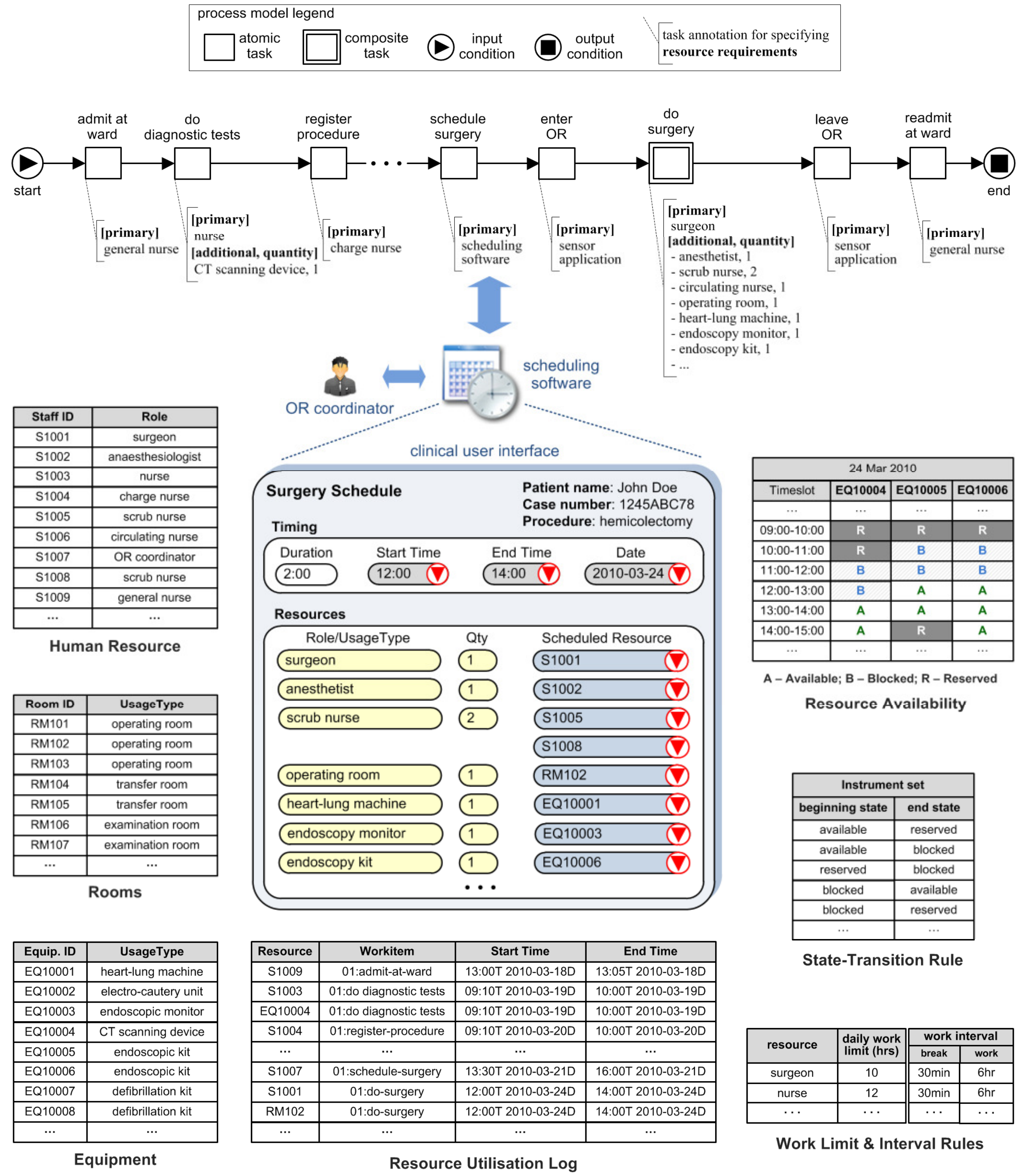


Figure 5: An example of a simplified perioperative care process

For planned (elective) cases, a perioperative care process begins with the admission of a patient to a hospital's ward and ends with the post-operative readmission of the patient at the ward. Both “admit at ward” or “readmit at ward” tasks are performed by a general nurse. Before a patient can be registered for surgery, it is necessary to “do diagnostic tests” on a CT scanning device by a nurse. Next, “register procedure” is an administrative task performed by a charge nurse. Then, the surgery needs to be scheduled which includes scheduling of the multiple resources required to carry out the surgery. The “schedule surgery” task is a complex administrative task and is usually performed by a scheduling software with which an operating room coordinator (OR coordinator) interacts via a clinical user interface. Next, for the purposes of illustration we assume the event of a patient entering or leaving an operation room may be captured by auto-ID sensors, and upon occurrence of the event the corresponding sensor application will enact tasks “enter OR” and “leave OR” as the primary resource used by both tasks. Finally, the surgery is carried out at the scheduled time when all the required resources are available.

In addition to the annotated process model, Figure 5 also shows examples of resource data tables that can be generated from our resource conceptual model. In the centre is an example of a surgery schedule that is created upon enactment of task “schedule surgery”. Scheduling of times and available resources is a result of interacting with the related resource data tables and it is important that these tables are complete. For example, assume that the surgery time is determined (e.g., from 12:00–14:00 on 24 March 2010) and we need to find an available instrument set (e.g. an endoscopic kit). The “Equipment” table shows three endoscopic kits: EQ10004, EQ10005 and EQ10006. The “Resource Availability” table shows that both EQ10005 and EQ10006 are available during the scheduled time period. However, after the reservation ends at 14:00, EQ10005 will need to be blocked for sterilisation. The “sterilisation after use” rule is captured by permitted state transitions from “reserved” to “blocked” and then “blocked” to “reserved” (or “available”) rather than from “reserved” (by one surgery operation) to “reserved” (by another surgery operation) as recorded in the “State-Transition Rules” table. Since EQ10005 is booked for another operation starting at 14:00, it cannot be reserved for the current operation which will end at the same time. As a result, only EQ10006 is available and is thus booked for the surgery operation.

CONCLUSION AND FUTURE WORK

In this paper we have presented a rich data model for workflow resources that could be supported in a BPMS. The model is derived from our own experience in developing business process models in different application domains. Our main objectives were (1) to find a way to represent the true nature of resources’ participation within business processes; (2) to extend the current resource perspective supported in process automation systems; and (3) to support semi-automated resource scheduling and assignments based on complex business rules. We validated the resulting resource model with a practical case study from the healthcare domain.

The next steps in our research include the development of a logical database design based on the conceptual model, the definition of functional requirements for a sophisticated resource management service, and a prototype implementation of such a resource management service within a state-of-the-art BPMS. For instance, one of the key functional requirements is that such a service should allow for advanced resource allocation strategies based on the resource availability statuses obtained from the resource calendars in real time. This resource management service will also serve as a core component for extending current BPMSs to support resource-intensive and schedule-driven business processes in various domains. To this end, we are currently working on extending the YAWL system with such a resource management service and certain scheduling capabilities to support resource-intensive and schedule-driven processes for perioperative care. As part of the future plan, the resulting system will be evaluated through its deployment in a real clinical environment.

On the other hand, the conceptual model presented in this paper serves as a starting point for further work in the areas of security-aware resource management (e.g., taking into account access control and authorisation privileges associated with resources) and cost-aware resource management (e.g., taking into account the cost of resources involved and making appropriate resource assignment decisions based on such information).

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